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Changes in cancer mortality in Shandong Province, China: a large population based study

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ABSTRACT

Objective: To analyze the trend of major malignant tumor mortality in Shandong Province, eastern China from 1970 to 2021, and to provide the scientific basis for malignant tumor prevention and control.

Methods: Cancer mortality data were sourced from three nationwide cause-of-death surveys and the Shandong Death Registration System. Trends in overall mortality and major causes of death were elucidated through indicators such as mortality rates and age-adjusted death rates, by comparing findings from the three comprehensive mortality surveys and the Shandong Death Registration System. The difference decomposing method was employed to estimate the contributions of non-demographic and demographic factors to the observed changes in cancer mortality.

Results: From 1970 to 2021, the crude mortality rate of malignant tumors witnessed an overall increase in Shandong Province. The age-standardized mortality rate initially rose before subsequently declining. The proportion of cancer deaths among all causes of death increased initially and then stabilized at a high level of approximately 25 %. Both non-demographic and demographic factors played a role in the rise of the crude cancer mortality rate, with the proportion attributed to demographic factors gradually surpassing that of non-demographic factors. Despite the continuous increase in the crude mortality rate, the adjusted mortality rate exhibited a downward trend since 1990. Significant changes were observed in the ranking of the mortality rates of major cancers. For example, the mortality rate of lung cancer exhibited a continuous upward trajectory, ascending from the fifth to the first place and marking a 7.69-fold increase from 1970 to 2021. Conversely, digestive system tumors, including gastric cancer, esophageal cancer, and liver cancer, displayed varying degrees of decline, particularly in the standardized rates, which demonstrated a notable downward trend since 1990. The crude mortality rate of colorectal cancer and breast cancer showed an obvious upward trend, but the standardized rate did not rise significantly. For cervical cancer, both the crude and adjusted mortality rates displayed a pattern of initially decreasing and then increasing.

Conclusions: Malignant tumors remain a significant threat to the residents of Shandong Province. The changing trends in various malignant tumors are inconsistent, underscoring the need for tailored intervention strategies to effectively control different types of malignant tumors.

1. Introduction

Cancer poses a significant challenge to public health and has emerged as a leading cause of death in China.[1] Given the country's vast population, the global impact of cancer is notably influenced by its prevalence in China.[2,3] According to the GLOBOCAN 2022 report,[2] an estimated 9.74 million cancer-related deaths and almost 19.98 million new cancer cases occurred globally in 2022. China accounted for approximately 26.42 % of global cancer deaths and 24.15 % of the global cancer cases, with both the incidence and mortality rates surpassing the global averages.

There is a scarcity of published data regarding cancer mortality trends in China over the past fifty years. Shandong, situated in eastern China, has the second-largest population among all provinces, com-

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prising about 98.5 million people, or about 7.2 % of the total Chinese population.[4]

Since the 1970s, three retrospective investigations into all causes of death had been conducted in Shandong Province. These surveys consistently revealed that malignant tumors had always been the second leading cause of death in Shandong Province, following cardiovascular and cerebrovascular diseases. The mortality rate attributed to cancer had been on the rise, with its proportion in total mortality steadily increasing. Cancer stands out as a major health concern, significantly jeopardizing the well-being of residents in Shandong Province. Since 2010, comprehensive monitoring of causes of death has been implemented across all counties and cities in Shandong, which provides a foundation for dynamically understanding overall mortality rates, composition, and changing trends of all causes of death, including malignant tumors, among residents in the province.[5,6] This study aims to analyze the trends in cancer mortality rates in Shandong Province from 1970 to 2021 and investigate the roles played by demographic and non-demographic factors in driving these changes.

2. Materials and methods

2.1. Data source

The Shandong Death Registration System (SDRS), which was officially established in 2006, first covered the Disease Surveillance Points (DSPs) in this province. Since 2010, the SDRS has expanded its coverage to encompass data collection from the entire population of Shandong Province.[5,6] In this study, a case was defined as the death of a resident in Shandong due to malignant tumors according to the International Classification of Diseases (10th revision ICD-10).[7] The cancer cases analyzed for years 2011–2013 and 2020–2021 were sourced exclusively from this system. To address underreporting, death data were adjusted using underreporting surveys (the capture-mark-recapture method) and incorporating official reports from the Household Registration System in China.[8-10]

The national retrospective survey of mortality spans several decades. An extensive retrospective study of causes of death was conducted in 29 provinces of China, including Shandong, in the 1970s.[11] This survey included all counties and cities in Shandong Province for the period of 1970–1974. The second national retrospective survey on all causes of death took place in 1990–1992, employing a stratified sampling method and covering approximately 10 % of the population in China.[12,13] 12 counties and 12 cities from Shandong Province were included as sampling areas. During 2006, 31 provinces, municipalities, and autonomous regions) conducted a national retrospective survey of all causes of death between 2004 and 2005. This survey covered 10 counties and 7 cities in Shandong Province.[14]

2.2. Statistical analysis

The classification of malignant tumors in this study adhered to the internationally recognized ICD-10 codes.[7] The age-standardized mortality rate (ASMR) and crude mortality rate (CMR) were calculated as observational indicators. In order to facilitate comparison with data from different periods, ASMR was calculated using the Segi's world standard population. The age-specific population (0-, 1–4, 5–84 years by 5-year intervals and 85+ years) of the year corresponding to the death data was obtained from the statistical yearbook of Shandong Province and the registered residence data of the public security bureau. To estimate the contribution of non-demographic and demographic factors to the change in CMR during different time periods, a difference decomposing method was applied in this study.[15,16] Demographic factors refer to the differences in cancer mortality rates caused by different population age structures (i.e., population aging). All other influencing factors, except for this factor, were classified as non-demographic factors. Due to the multitude of factors affecting cancer, different cancers had different risk factors. Therefore, in this study, factors other than population aging were all categorized as non-demographic factors. The mortality rate in year b (Rb) -The mortality rate in year a (Ra) = Contribution value of demographic factor (Vd) + Contribution value of non-demographic factors (Vn). When the population structure in year a is taken as the standard population to calculate the standard rate in year b (Rbs), then Vn = Rbs - Ra and Vd = Rb - Rbs. The constituent ratio of demographic factor (Cd) = Vd/(Rb-Ra)×100 %.[5] The calculation formula and detailed introduction of this method can be found in, for example, Yang GH and our previous publications.[5,15,16]

3. Results

3.1. Changes in cancer mortality

Since the 1970s, the percentage of deaths attributable to malignant tumors among all causes of death in Shandong Province has shown a continuous increase. It escalated from 11.46 % in 1970–1974 to 19.12 % in 1990–1992, reaching a peak of 25.97 % in 2004–2005, and has since consistently maintained a high proportion of over 20 %. The mortality rate of malignant tumors is higher in males than that in females, and the demographic changes in male and female populations over different periods exhibited general consistency, as illustrated in Figs. 1, 2. The ranking of cancer among all causes of death ascended from the 4th in the 1970s to the 3rd in 1990–1992, and further to the 2nd in 2004–2005. Since 2005, it has consistently held the second place among all causes of death (Table 1).

Since the 1970s, the crude mortality rate of cancer in Shandong Province has shown a persistent increase, with the upward trend slowing down notably after 2004–2005 (Fig. 3). Specifically, the crude mortality rate witnessed increments of 53.51 %, 41.42 %, 5.39 %, and 7.07 %, respectively, for the periods of 1990–1992, 2004–2005, 2011–2013, and 2020–2021, compared to their preceding periods. However, the adjusted mortality rate displayed an ascending trajectory from 1970–1974 to 2004–2005, followed by a declining trend post 2004–2005 (Fig. 4). This suggests that the increase in crude mortality rate after the 1990s was primarily attributed to changes in the population structure, specifically an aging population. Further analysis through differential decomposition of mortality revealed that the surge in cancer mortality from the 1970s to the 1990s was predominantly influenced by non-demographic factors, accounting for 95.10 %, while demographic factors contributed only 4.90 % (refer to Fig. 5). However, post the 1990s, the proportion of population factors leading to an increase in mortality rates grew substantially. For example, in 2004–2005 and 2011–2013, the proportion of population factors reached 39.96 % and 62.27 %, respectively. By 2020–2021, the influence of population factors surged to 84.53 %.

3.2. Changes in the ranking of malignant tumor deaths

Significant transformations had occurred in the ranking of deaths from major cancers in Shandong Province since the 1970s. Notably, the ranking of stomach cancer declined from the first place in the 1970s and 1990s to the third place in 2011–2013. Esophageal cancer experienced a drop from the second place in the 1970s to the fourth place in 2020–2021. The most pronounced increase was observed in lung cancer mortality, progressing from the fifth place in the 1970s to the third place in the 1990s, ultimately claiming the first position in 2004–2005 and maintaining this status since then. Cervical cancer, once the leading cause of cancer death in women in the 1970s and the fourth cause of cancer death in the overall population, declined to the seventh position in the overall population in the 1990s and dropped out of the top 10 in 2011–2013. The detailed changes in the death order of each major tumor were presented in Table 2.

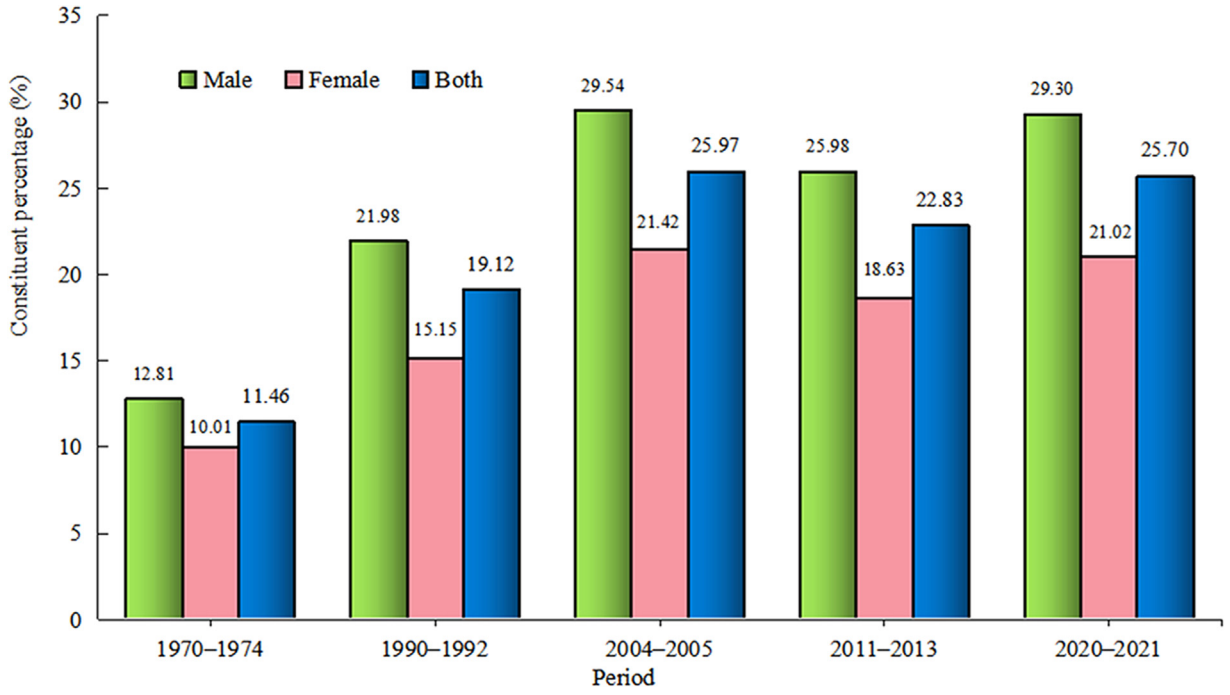


Fig. 1. The proportion of malignant tumor deaths among the total causes of death in males and females in different time periods.

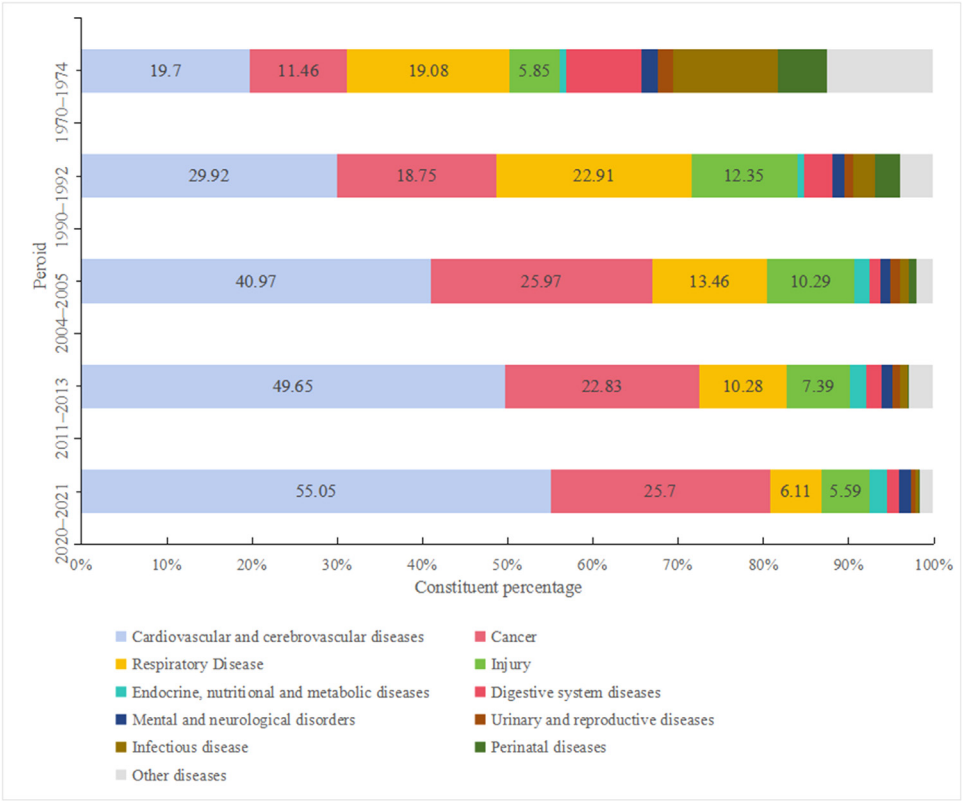


Fig. 2. Composition of main causes of death in different time periods in Shandong Province.

3.3. Mortality changes and differential decomposition of major malignant tumors

The crude mortality rates of lung cancer, colorectal cancer, and breast cancer exhibited an upward trend (Fig. 6). Among them, lung cancer mortality showed the most rapid increase, surging from 7.22/100,000 in the 1990s to 62.73/100,000 in 2020–2021, a staggering 7.69-fold increase. Stomach cancer, esophageal cancer, and liver cancer displayed an upward trend from the 1970s to 2004–2005, followed by a subsequent decline in their crude mortality rates. Even after adjustment using Segi's world standard population, the mortality rate of lung cancer continued to rise until 2011–2013 (Fig. 7). Conversely, the standardized mortality rate of esophageal cancer showed a consistent downward trend. Stomach cancer, liver cancer, and colorectal cancer

Table 1
Ranking of main causes of death, composition of deaths, and mortality rate in Shandong Province in different years.

Cause of death	1970–1974			1990–1992			2004–2005			2011–2013			2020–2021		
	Rank	%	CMR, 1/10^5	Rank	%	CMR, 1/10^5	Rank	%	CMR, 1/10^5	Rank	%	CMR, 1/10^5	Rank	%	CMR, 1/10^5
Cardiovascular and cerebrovascular diseases	1	19.70	132.67	1	29.92	184.02	1	40.97	266.69	1	49.65	382.41	1	55.05	403.36
Respiratory Disease	2	19.08	128.24	2	22.91	140.91	3	13.46	87.59	3	10.28	79.17	3	6.11	44.75
Infectious disease	3	12.27	82.45	7	2.56	15.74	9	1.02	6.64	8	0.88	6.77	9	0.42	3.10
Cancer	4	11.46	76.86	3	18.75	117.99	2	25.97	166.86	2	22.83	175.86	2	25.7	188.3
Digestive system diseases	5	8.82	59.25	5	3.29	20.25	6	1.30	8.45	6	1.79	13.79	6	1.41	10.31
Injury	6	5.85	39.33	4	12.35	75.93	4	10.29	66.97	4	7.39	56.91	4	5.59	40.92
Perinatal diseases	7	5.73	38.49	6	2.99	18.40	10	0.94	6.15	10	0.22	1.71	10	0.09	0.68
Mental and neurological disorders	8	1.90	12.75	8	1.38	8.49	8	1.11	7.25	7	1.33	10.25	7	1.36	9.99
Urinary and reproductive diseases	9	1.87	12.55	9	1.01	6.24	7	1.14	7.39	9	0.80	6.16	8	0.57	4.21
Endocrine, nutritional and metabolic diseases	10	0.76	5.13	10	0.87	5.38	5	1.78	11.61	5	1.90	14.62	5	2.03	14.83
Obstetric diseases	11	0.34	2.30	11	0.11	0.65	11	0.03	0.21	11	0.02	0.16	11	0	0.02
Total		100.00	739.39		100.00	615.3		100.00	650.96		100.00	770.18		100.00	732.73

Abbreviation: CMR, crude mortality rate.

Table 2
Mortality rate of the main malignant tumors in Shandong Province in different years.

Rank	1970–1974				1990–1992				2004–2005				2011–2013				2020–2021			
	Site	Male, 1/10^5	Female, 1/10^5	Both, 1/10^5	Site	Male, 1/10^5	Female, 1/10^5	Both, 1/10^5	Site	Male, 1/10^5	Female, 1/10^5	Both, 1/10^5	Site	Male, 1/10^5	Female, 1/10^5	Both, 1/10^5	Site	Male, 1/10^5	Female, 1/10^5	Both, 1/10^5
1	Stomach	24.50	12.12	18.33	Stomach	38.46	20.09	29.43	Lung	54.26	30.94	42.71	Lung	74.58	37.57	56.37	Lung	83.66	41.19	62.73
2	Oesophagus	24.05	10.10	17.59	Liver	30.82	13.04	22.08	Stomach	45.41	22.71	34.15	Liver	43.03	16.31	29.89	Stomach	36.28	16.03	26.30
3	Liver	13.81	5.60	9.72	Lung	28.51	14.39	21.57	Liver	43.41	17.24	30.44	Stomach	38.93	17.74	28.51	Liver	36.93	14.54	25.90
4	Cervix	–	17.21	8.58	Oesophagus	24.07	12.18	18.22	Oesophagus	28.83	12.45	20.71	Oesophagus	23.76	7.94	15.98	Oesophagus	21.77	6.65	14.32
5	Lung	9.32	5.11	7.22	Colorectum	5.62	4.49	5.06	Colorectum	7.62	5.73	6.68	Colorectum	9.68	7.28	8.50	Colorectum	13.84	9.89	11.89
6	Colorectum	3.85	2.95	3.40	Leukaemia	4.25	3.66	3.96	Leukaemia	4.86	3.85	4.36	Breast	0.24	8.16	4.13	Pancreas	6.96	5.13	6.05
7	Leukaemia	2.36	1.78	2.07	Cervix	–	4.23	2.08	Brain, CNS	3.73	2.94	3.34	Pancreas	4.68	3.30	4.00	Breast	0.14	9.83	4.91
8	Breast	0.65	3.46	1.75	Breast	0.04	3.32	1.65	Breast	0.02	6.62	3.29	Leukaemia	4.67	3.27	3.98	Leukaemia	4.62	3.41	4.02
9	Nasopharynxt	1.36	1.00	1.18	Bladder	2.04	0.63	1.35	Pancreas	3.39	2.74	3.07	Brain, CNS	4.34	3.51	3.93	Lymphoma	3.56	2.29	2.93
10	Brain, CNS	1.22	1.02	1.12	Nasopharynxt	0.96	0.62	0.79	Bone	2.54	1.78	2.16	Lymphoma	3.69	2.34	3.03	Bladder	3.68	0.95	2.34

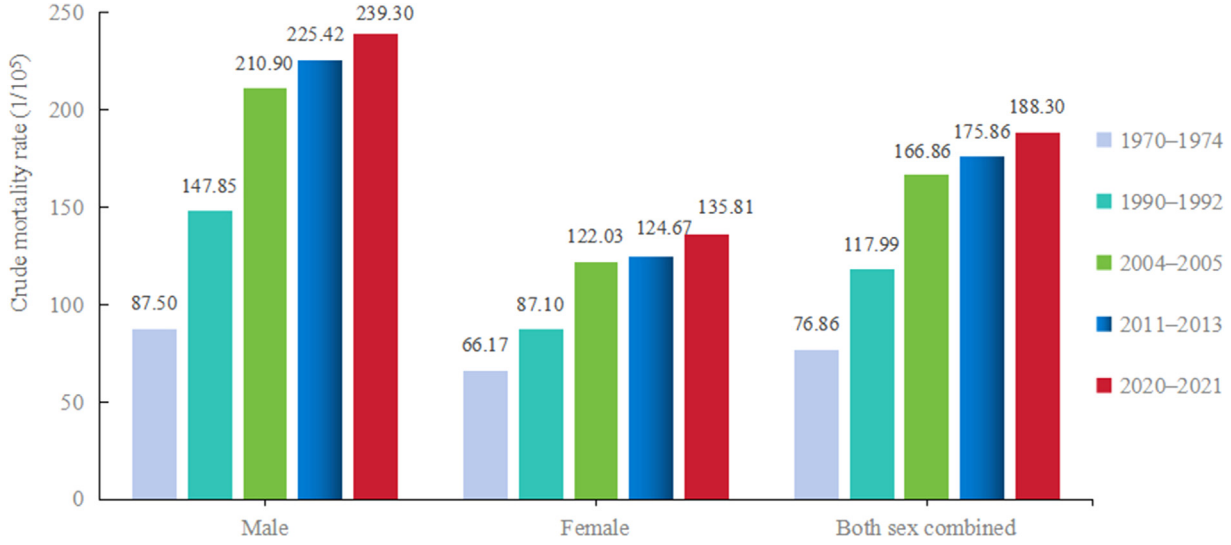


Fig. 3. Trends of crude mortality rates of malignant tumors in different time periods in Shandong Province.

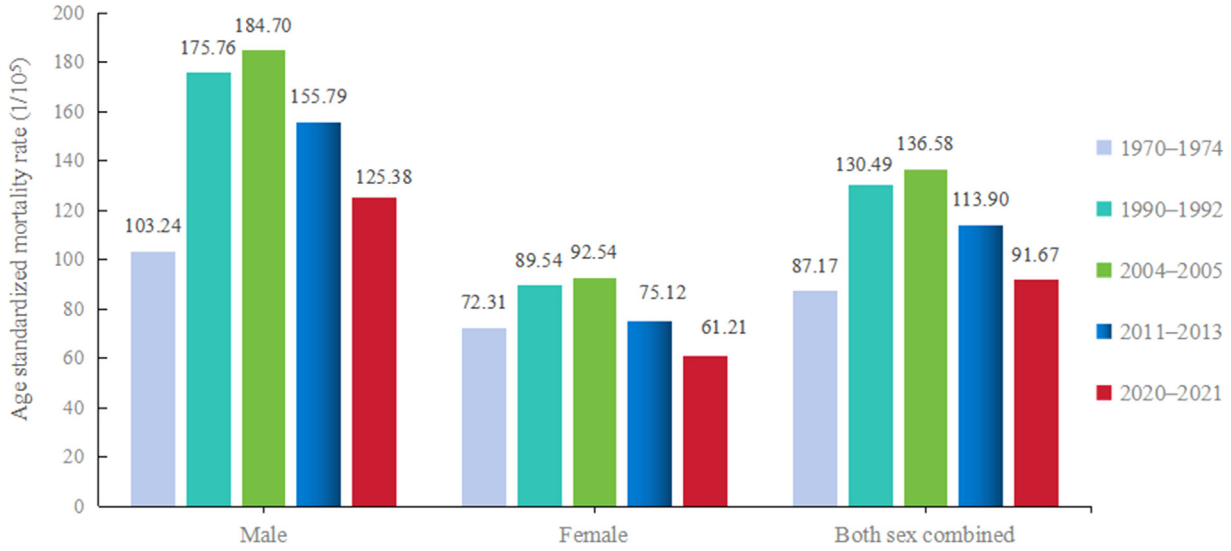


Fig. 4. Trends in standardized mortality rates of malignant tumors in different time periods in Shandong Province.

demonstrated an upward trend from the 1970s to the 1990s, remaining stable or decreasing after the 1990s. The crude and adjusted mortality rates of cervical cancer exhibited an initial rapid decline followed by a slow increase.

Fig. 8 showed the results of the decomposition of the differences in the mortality of major malignant tumors between 2020 and 2021 and the 1970s. With the exception of stomach cancer, esophageal cancer, and cervical cancer, the increase in mortality for other tumors resulted from the synergistic effect of demographic and non-demographic factors. The rose in mortality from liver cancer, colorectal cancer, and breast cancer was predominantly caused by demographic factors (population aging), accounting for 72.11 %, 62.72 %, and 66.42 % of the total increase, respectively. The increase in lung cancer and leukemia mortality was primarily attributed to non-demographic factors, accounting for 59.80 % and 57.03 % of the total increase, respectively. Gastric cancer mortality increased solely due to demographic factors, while non-demographic factors contributed to the reduction in mortality. The decline in esophageal and cervical cancer mortality was solely due to non-demographic factors, with demographic factors partially offsetting the decline.

4. Discussion

Cancer has emerged as a leading cause of death globally, posing a significant challenge to increasing life expectancy in all countries.[17] Incidence and mortality rates of cancer have been on the rise worldwide.[18] Since 2010, cancer has become the leading cause of death among Chinese residents,[19] with the 2016 China Statistical Yearbook reporting it as the most common cause of death in urban and rural areas, accounting for 26.44 % and 23.22 % of all deaths, respectively.[20] On a global scale, cancer caused approximately 16 % of global deaths in 2015, totaling 8.7 million.[21] The Global Burden of Disease Study 2019 reported a total of 10 million cancer deaths worldwide in 2019, a 20.9 % increase from 2010 (8.29 million).[22] The global proportion of cancer deaths increased from 15.7 % in 2010 to 17.7 % in 2019.[22]

This study revealed that in Shandong Province the proportion of malignant tumor deaths among all causes of death has steadily increased since the 1970s.In the 1990s, it more than doubled compared to the 1970s. The proportion of cancer deaths in Shandong Province was higher than the global average but lower than that in Beijing (26.8 %),[23] with a comparable level to neighboring Hebei Province.[24] In this study

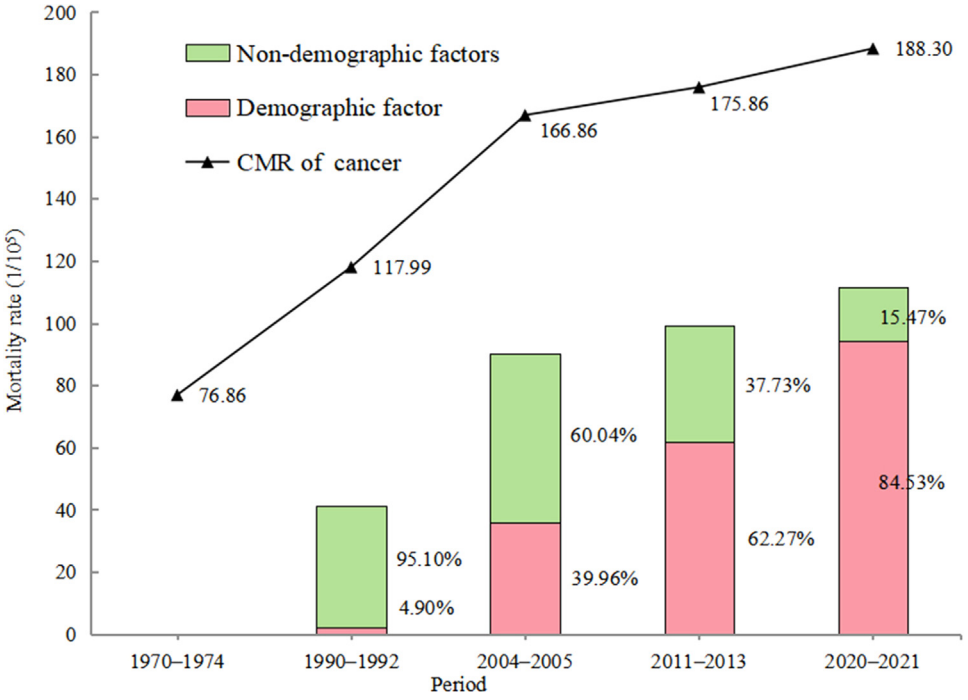


Fig. 5. Difference decomposition of cancer mortality rates in different time periods. CMR, crude mortality rate.

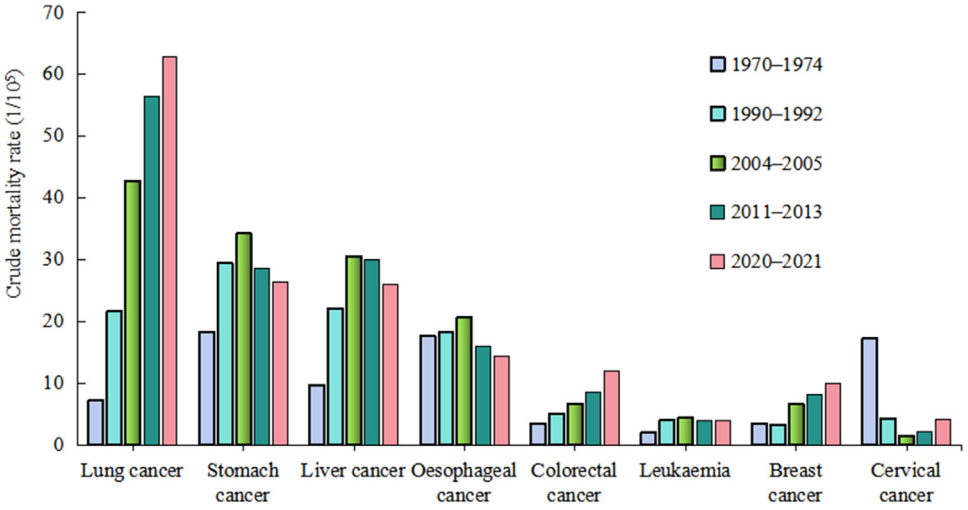


Fig. 6. Crude mortality rate of major malignant tumors in Shandong Province in different time periods.

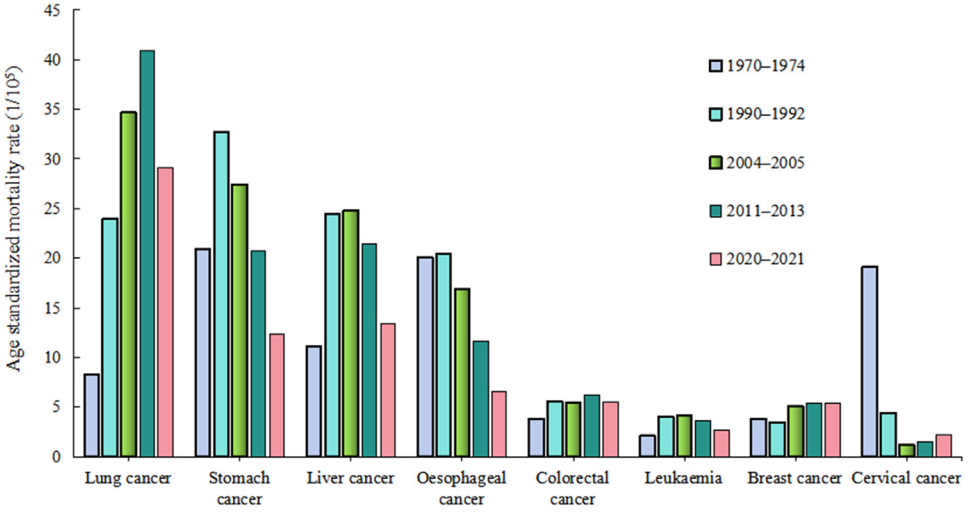
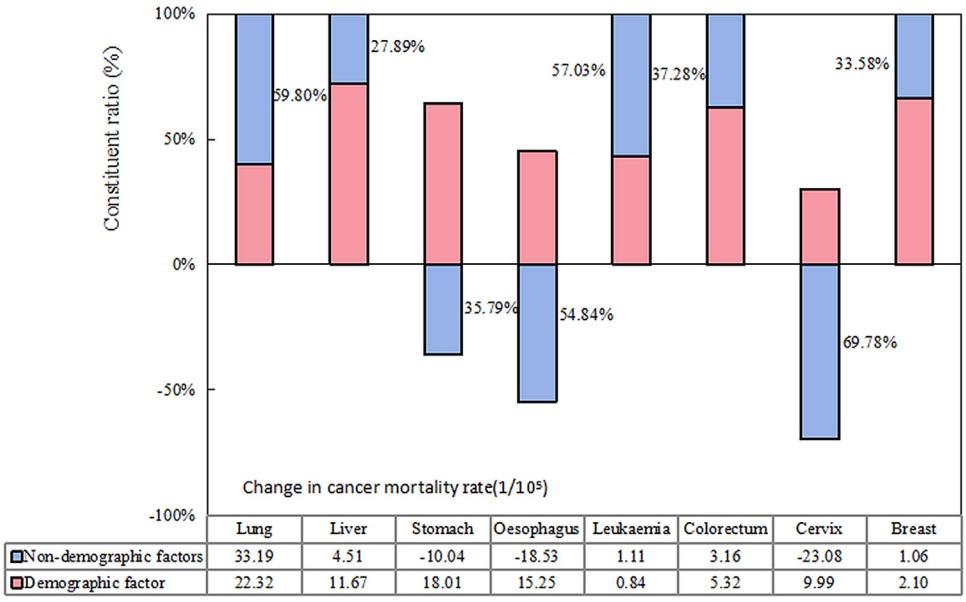


Fig. 7. Standardized mortality rate of major malignant tumors in Shandong Province in different time periods.



	Lung	Liver	Stomach	Oesophagus	Leukaemia	Colorectum	Cervix	Breast
Non-demographic factors	33.19	4.51	-10.04	-18.53	1.11	3.16	-23.08	1.06
Demographic factor	22.32	11.67	18.01	15.25	0.84	5.32	9.99	2.10

Fig. 8. Differential decomposition of mortality of major cancers between 2020 and 2021 and 1970–1974 in Shandong Province.

we found that the overall crude mortality rate of malignant tumors in Shandong Province had been on the rise from 1970 to 2021, while the age-standardized mortality rate showed a downward trend after the 1990s. This suggested that the increase in crude mortality rate after the 1990s was primarily due to changes in population structure, specifically an aging population. Differential decomposition of mortality revealed that the increase in cancer mortality from 2011 to 2013 was mainly caused by demographic factors, with the proportion of demographic factors reaching 62.27 % in 2011–2013 and 84.53 % in 2020–2021. A study in Fujian Province similarly found an increase in the mortality rate of malignant tumors, increased by 56.49/10^5 in 2008–2009 compared with 1973–1975, with demographic and non-demographic factors contributing 82.23 % and 17.77 %, respectively.[25] Population factors thus played a crucial role in the increase in cancer mortality rates in both provinces.

Changes in the order of the causes of death for malignant tumors in Shandong Province since the 1970s had been notable. Lung cancer mortality exhibited the most rapid increase, with the crude mortality rate increased from 7.22/100,000 in the 1990s to 62.73/100,000 in 2020–2021, a 7.69 times increase. This aligned with national trends in the cause of death spectrum[26,27] and may be attributed to factors such as smoking, and indoor and outdoor air pollution.[5,28] Stomach cancer ranks as the second most prevalent cause of malignant tumor-related mortality, with the crude and standardized mortality rates of stomach cancer exhibiting an initial increase followed by a subsequent decrease, aligning with previous findings in Hebei Province.[11] Moreover, the mortality/incidence ratio for stomach cancer is 2.56 times higher than that in South Korea.[29] These statistics underscore the imperative for intensified interventional strategies, as well as the implementation of early diagnosis and treatment measures.

The mortality rates of esophageal cancer have shown a decline in both crude and standardized measures, indicating successful efforts in controlling risk factors and implementing preventive measures. Conversely, lung cancer, colorectal cancer, and breast cancer have experienced an increase in mortality rates attributed to a combination of demographic and non-demographic factors, highlighting the persistent challenges in managing these risk factors. The research results of GBD 2019 (Global burden of disease 2019) also showed that the age standardized incidence rate [including incidence rate, mortality, and disability-adjusted life year(DALY)] of esophageal cancer has been declining globally since 1990.[30] Although demographic factors (aging) can lead to a relatively higher mortality rate, non-demographic factors (such as more healthy lifestyles, early detection and treatment, improved health awareness, increased knowledge of tumor prevention and control, etc.) have a stronger impact, resulting in a decrease in esophageal cancer mortality rate. This indicates that the risk factors for esophageal cancer in Shandong Province have been controlled to a certain extent, and relevant prevention and control measures have been effective. Other cancers, such as lung cancer, colorectal cancer, and breast cancer, had increased mortality due to the combined effect of demographic factors and non-demographic factors, indicating that the risk factors for these tumors have not been improved or have even increased. For example, risk factors related to lung cancer (such as smoking, indoor and outdoor air pollution, etc.) continue to exist. With the improvement of living standards and changes in lifestyles, increased intake of meat and physical inactivity can increase the mortality rate of colorectal cancer.

A study in China showed that in 2019, the total number of deaths from malignant tumors in people aged 25 and above in China was 2.69 million. Among these, the number of deaths attributable to population aging, adult population size, age-specific cancer incidence, and case fatality rate of malignant tumors were 740,000, 1,091,000, 198,000, and −728,000, respectively, accounting for 27.5 %, 40.6 %, 7.3 %, and −27.1 % of the total number of deaths in 2019.[31] China entered an aging society in 2000, with the proportion of the population aged 65 years and above exceeding 7 %, and entered a deeply aging society in 2021, with the elderly population accounting for >14 %. It is projected that around the year 2033, China will enter a super-aged society with the proportion exceeding 20 %, and this percentage will continue to rise rapidly to 35 % by 2060.[32] Due to the rapid development of population aging, it is expected that the overall crude mortality rate of malignant tumors in Shandong Province, especially of those that are currently increasing rapidly, such as lung cancer, colorectal cancer, and breast cancer, will continue to rise over the next 10 to 20 years. With the further improvement of early diagnosis rates, effective treatment rates, and survival rates, the age-standardized mortality rates for major cancers will further decrease. The aging of the population in China has been a significant factor in the growing burden of cancer, resulting in a higher number of cancer-related deaths than those caused by the age-specific cancer incidence. Therefore, initiatives focused on promoting healthy aging are essential for the prevention and management of cancer.

In conclusion, malignant tumors continue to be a significant health concern for residents of Shandong Province. The fluctuating patterns observed across different types of malignant tumors highlight the importance of adopting targeted intervention measures to effectively manage the diverse spectrum of cancerous conditions. We need to make further efforts in cancer prevention, early diagnosis, and effective treat-

ment. While controlling risk factors and reducing the incidence rate of cancer, new effective treatment methods, such as radiotherapy and immunotherapy, have also played a role in improving the survival rate of cancer and reducing mortality.[33] Comprehensive intervention measures should be taken for different tumors and risk factors, especially those with high mortality rates and a rapid growth, to further reduce the overall mortality rate of malignant tumors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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Author contributions

X.G, J.M, and A.X conducted the study design. Z.L, J.C, X.X, B.Z, and F.J collected the data. Z.F, F.J, and Z.L analyzed the data. Z.F and F.J created all figures and prepared the manuscript. X.G, A.X, and J.M conducted a thorough examination and made necessary modifications to the manuscript. The final version of the manuscript has been carefully reviewed and endorsed by all authors.

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